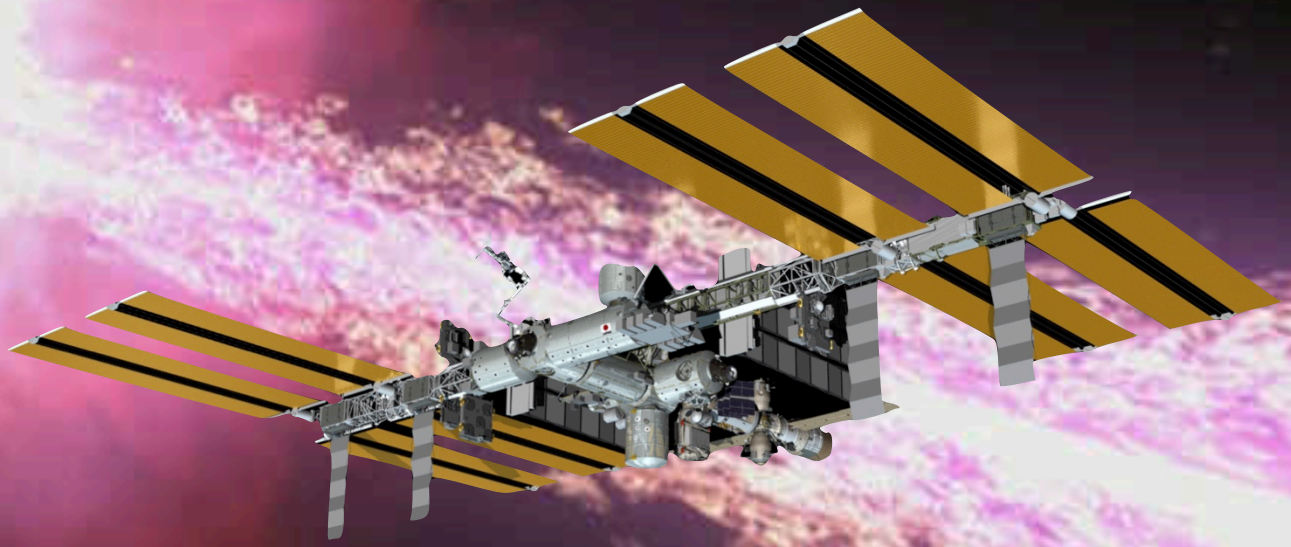
LEAP

LargE Area burst Polarimeter



Michael Briggs
University of Alabama - Huntsville

on behalf of the LEAP collaboration

LEAP Science Team

PI : Mark McConnell (UNH/SwRI)
Deputy PI : Jessica Gaskin (MSFC)
Project Scientist : Colleen Wilson-Hodge (MSFC)

Matthew Baring (Rice)
Peter Bloser (UNH)
Michael Briggs (UAH)
Valerie Connaughton (USRA)
Joseph Dwyer (UNH)
Eric Grove (NRL)
Shuichi Gunji (Yamagata Univ)
Dieter Hartmann (Clemson)
Kiyoshi Hayashida (Osaka Univ)
Joanne Hill-Kittle (GSFC)
Emily Jackson (NRL)
R. Marc Kippen (LANL)
Shunji Kishimoto (KEK)
John Krizmanic (GSFC)
Christoffer Lundman (Columbia Univ)
Sheila McBreen (UCD)
Chip Meegan (MSFC)

Tatehiro Mihara (RIKEN)
Takeshi Nakamori (Yamagata Univ)
Mark Pearce (KTH)
Bernard Phlips (NRL)
Rob Preece (UAH)
Nicolas Produit (ISDC)
Jim Ryan (UNH)
Felix Ryde (KTH)
Takanori Sakamoto (Aoyama Gakuin Univ)
Mark Strickman (NRL)
Steve Sturner (GSFC)
Hiromitsu Takahashi (Hiroshima Univ)
Kenji Toma (
W. Thomas Vestrand (LANL)
Yoichi Yatsu (Tokyo Institute Tech)
Daisuke Yonetoku (Kanazawa Univ)
Bing Zhang (UNLV)

What is LEAP?

- Proposed as a NASA Mission of Opportunity
- Large-Area, Wide-FoV Compton Polarimeter
- 50-500 keV polarimetry
- 20 keV - 5 MeV spectroscopy
- Externally attached to ISS
- Launch date ~2022
- Minimum two-year mission

Yamagata University
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
NASA
University of New Hampshire
SwRI SOUTHWEST RESEARCH INSTITUTE

LEAP will Tell Us About...

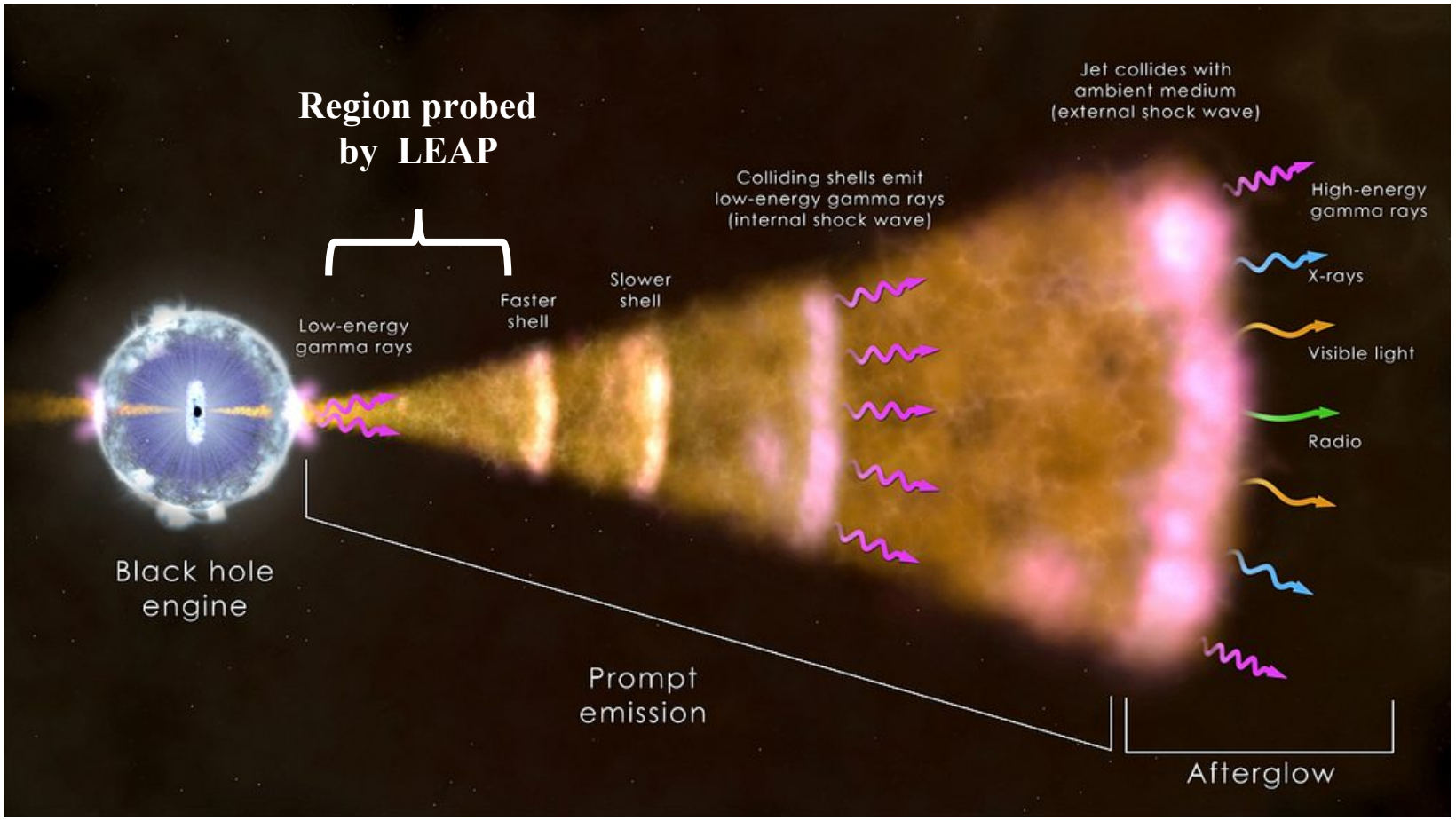
1 – JET COMPOSITION
Are jets matter-dominated or Poynting-flux dominated?

2 – JET ENERGY DISSIPATION MECHANISM
Is energy dissipated by shocks or magnetic reconnection?

3 – JET EMISSION MECHANISM
Is the jet radiation mechanism synchrotron or inverse Compton?

4 – JET GEOMETRY
What is the distribution of jet opening angles?

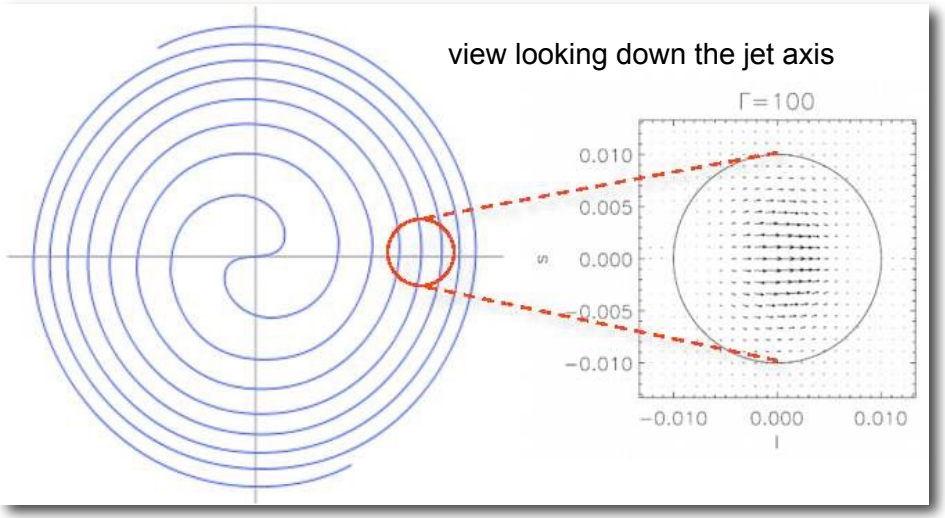
Anatomy of a Gamma-Ray Burst



Toroidal Magnetic Field Model

In the canonical view of a twisted magnetic field within the jet, the magnetic field is largely toroidal.

If observer sees the whole jet, polarization will average out to zero.



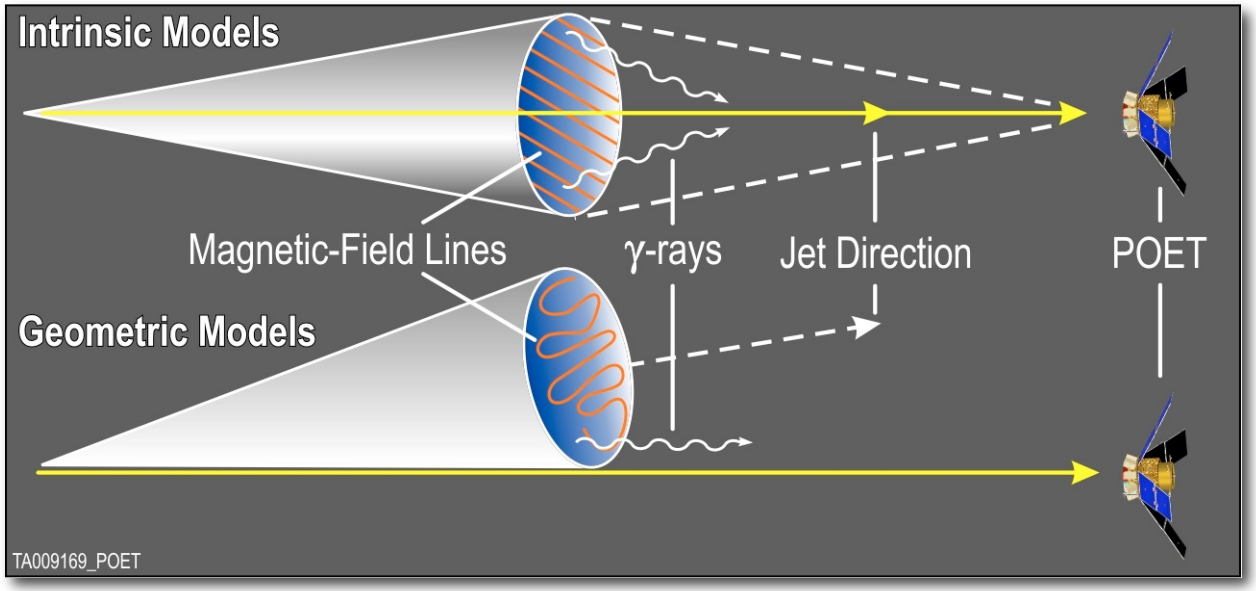
In a relativistic jet, the observers sees only a fraction of the total cross section, where the net polarization may be positive.

This model predicts large levels of polarization in almost all GRBs.

Importance of Viewing Angle

The viewing angle between the jet and the observer can also influence the degree of polarization.

A randomly oriented B-field structure may not average out the polarization signal if seen from off-axis.



from Waxman, Nature, 423, 388 (2003)

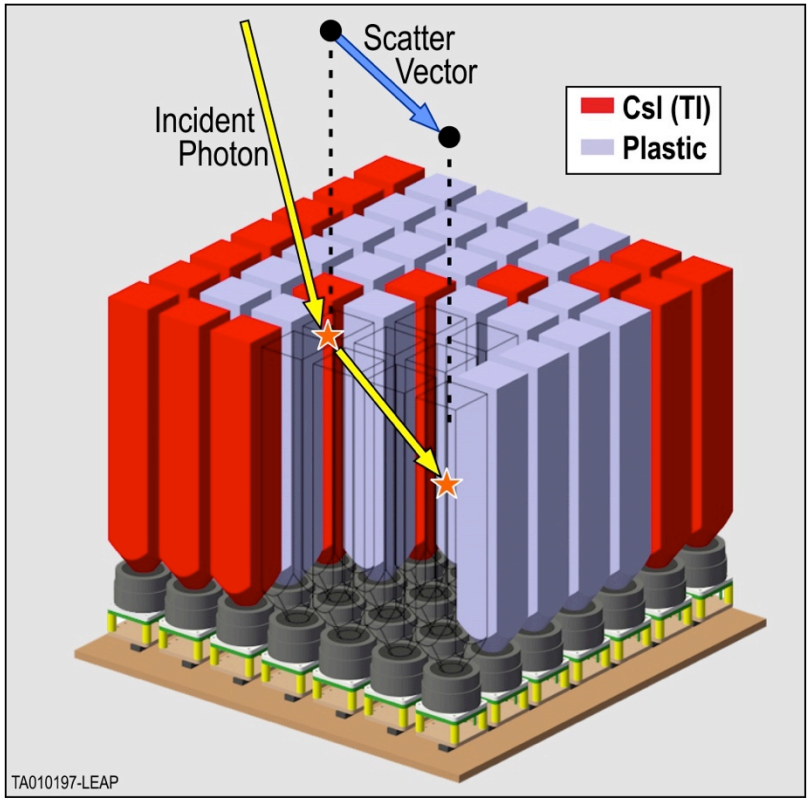
Results to Date

Results suggest very high polarization levels, but all are of limited statistical significance.

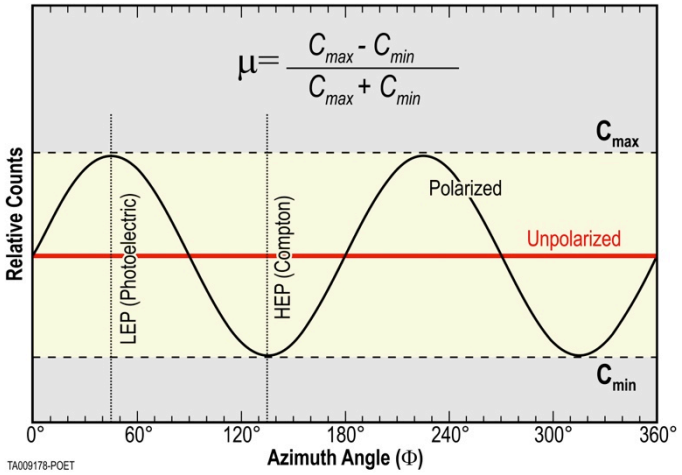
Event	*Mission*	*Energy (keV)*	*Result*	*Reference*
GRB 930131	CGRO/BATSE	20 - 1000	(35-100%)	Willis et al. (2005)
GRB 960924	CGRO/BATSE	20 - 1000	(50-100%)	Willis et al. (2005)
GRB 021206	RHESSI	150 - 2000	80% ± 20%	Coburn & Boggs (2003)
GRB 041219a	INTEGRAL/SPI	100 - 350	98% ± 33%	Kalemci et al. (2007)
GRB 041219a	INTEGRAL/SPI	100 - 350	96% ± 40%	McGlynn et al. (2007)
GRB 041219a	INTEGRAL/IBIS	200 - 800	43% ± 25% (variable π)	Götz et al. (2009)
GRB 061122	INTEGRAL/IBIS	250 - 800	> 60%	Götz et al. 2013
GRB 100826a	IKAROS/GAP	70 - 300	27% ± 11% (variable PA)	Yonetoku et al. (2011)
GRB 110301a	IKAROS/GAP	70 - 300	70% ± 22%	Yonetoku et al. (2012)
GRB 110721a	IKAROS/GAP	70 - 300	80% ± 22%	Yonetoku et al. (2012)
GRB 140206a	INTEGRAL/IBIS	200 - 800	> 48%	Götz et al. (2014)

Yamagata University · THE UNIVERSITY OF ALABAMA IN HUNTSVILLE · NASA · University of New Hampshire · SwRI Southwest Research Institute

Compton Polarimetry



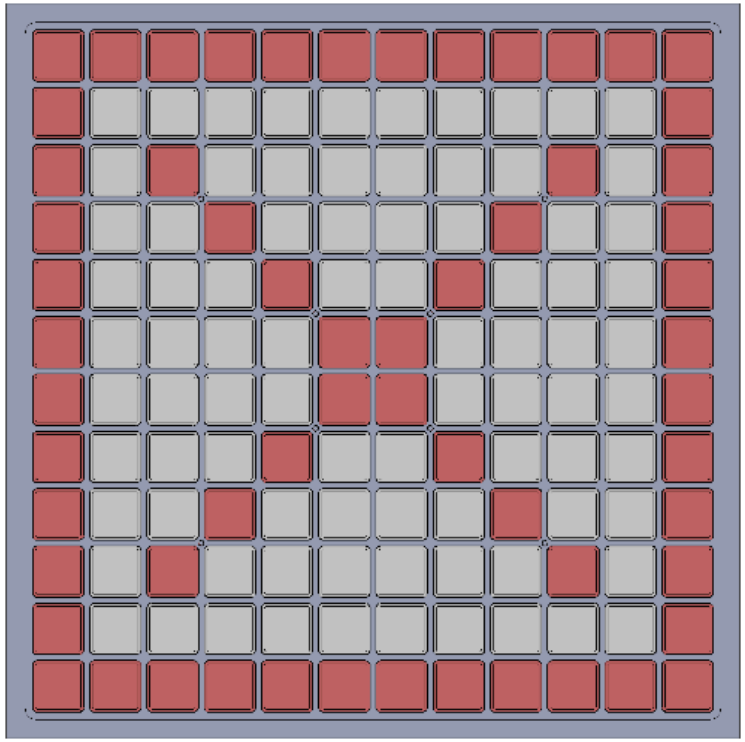
one quadrant of a LEAP module



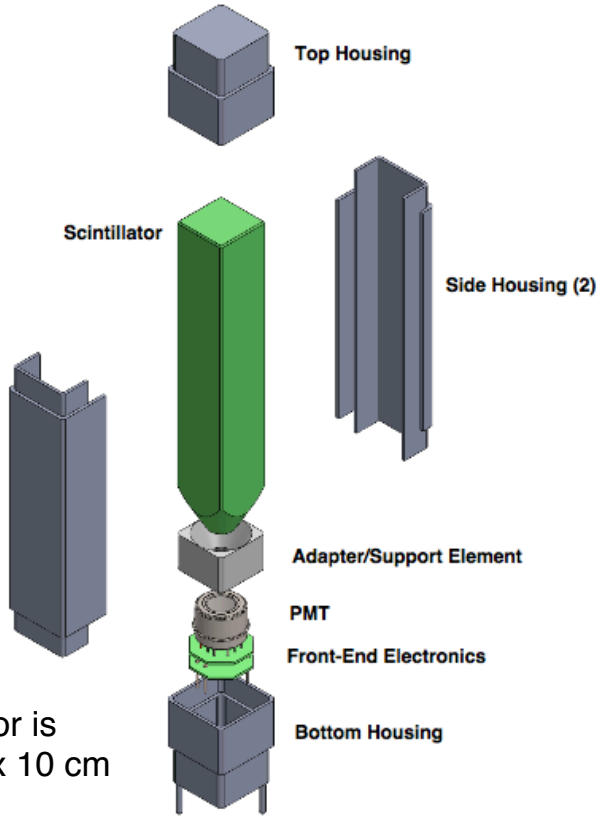
The LEAP instrument design is based on GRAPE balloon payload developed at UNH.

LEAP Scintillator Geometry

A single module consists of 144 discrete detector elements

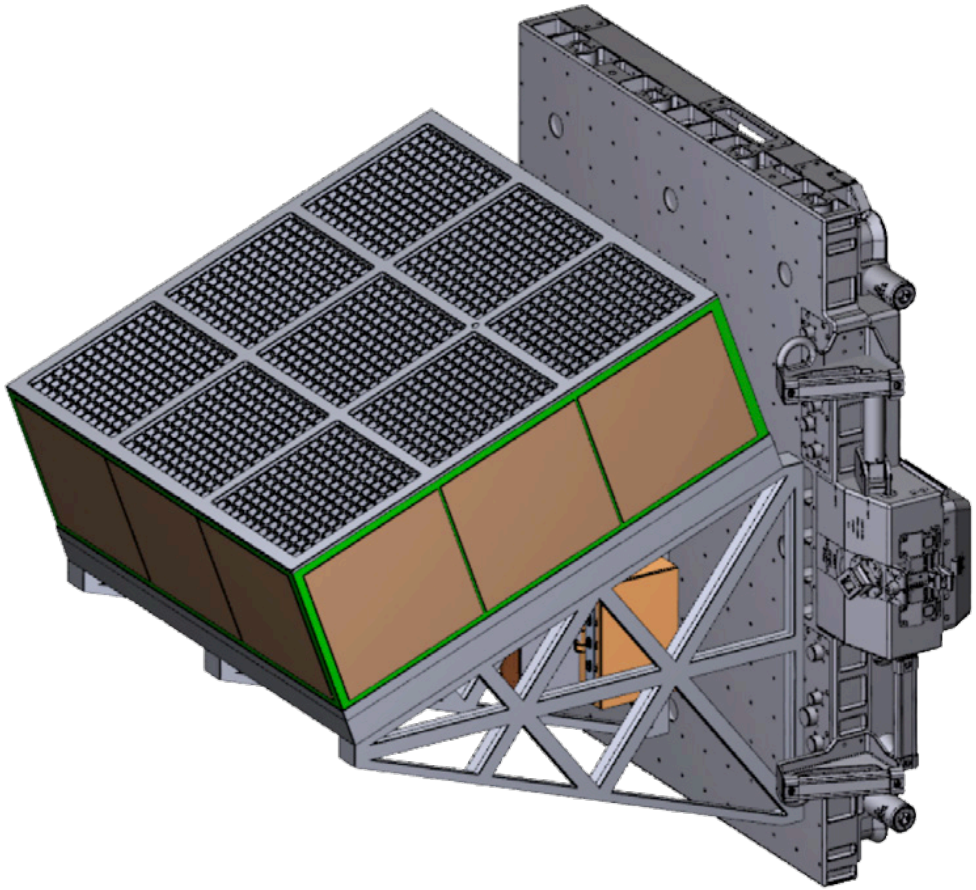


CsI plastic

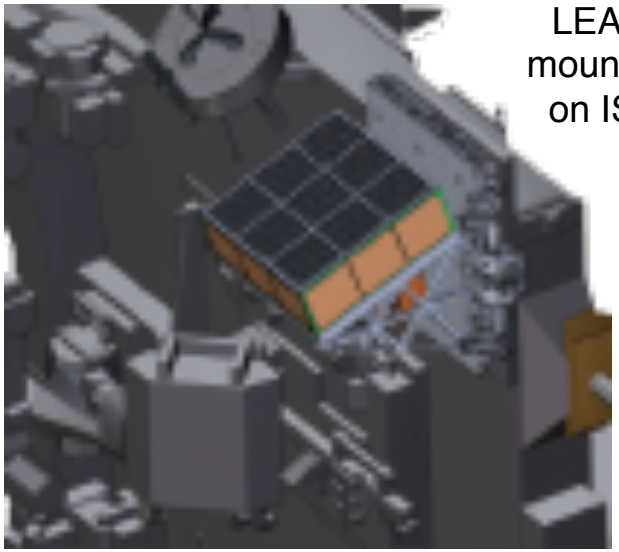


Each scintillator is
1.7 cm x 1.7 cm x 10 cm

LEAP Polarimeter Array



Full LEAP instrument consists of 9 independent polarimeter modules surrounded by passive Pb shielding on sides and bottom.



LEAP mounted on ISS

LEAP Performance

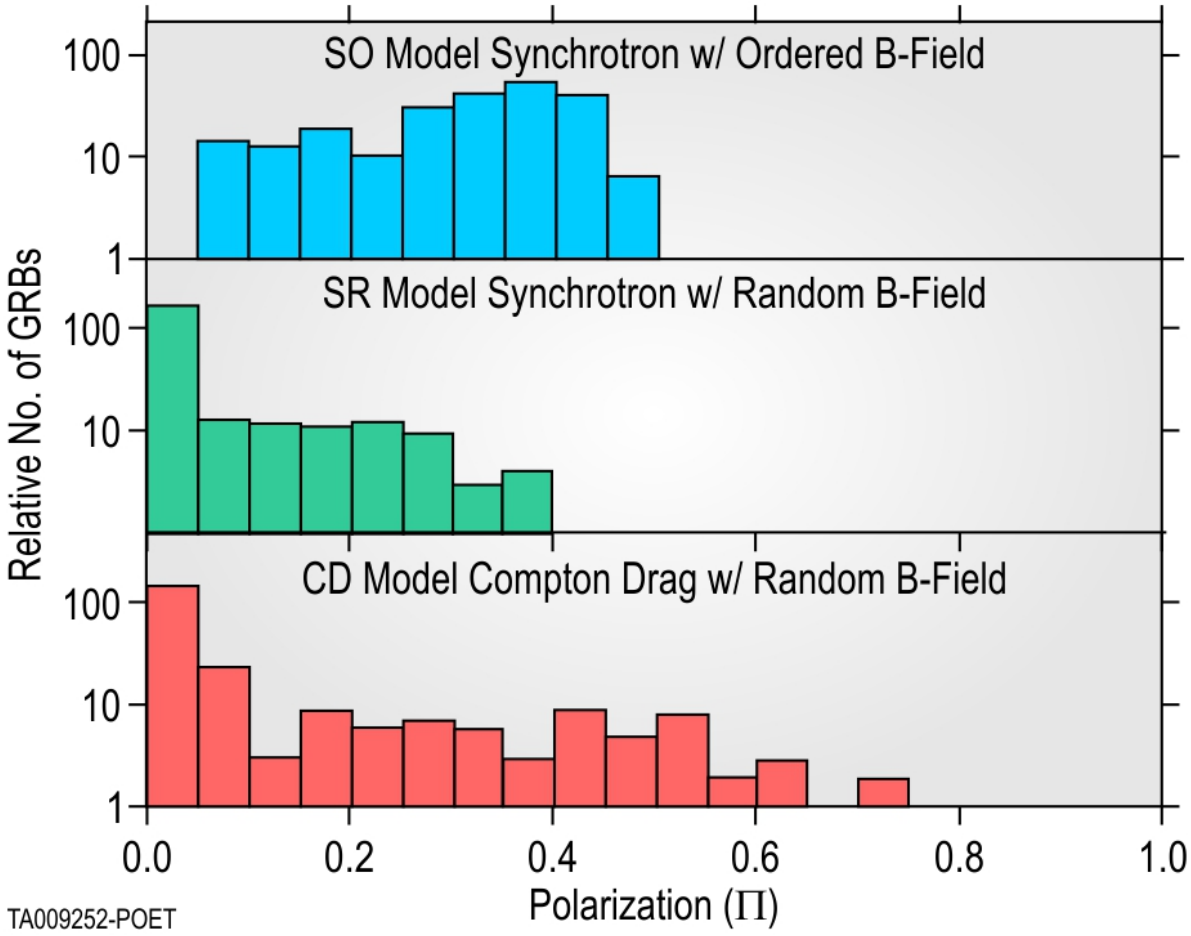
LEAP 2-year performance numbers are based on typical response characteristics. Background estimates are based on GBM and CALET data, and confirmed by simulations.

Number of GRBs Detected in 2 Years (PC events only)

	N < 5% MDP	N < 10% MDP	N < 15% MDP	N < 20% MDP
High Bgd (4.0 cts s^{-1} cm^{-2})	9	25	41	56
Low Bgd (2.6 cts s^{-1} cm^{-2})	10	31	51	68

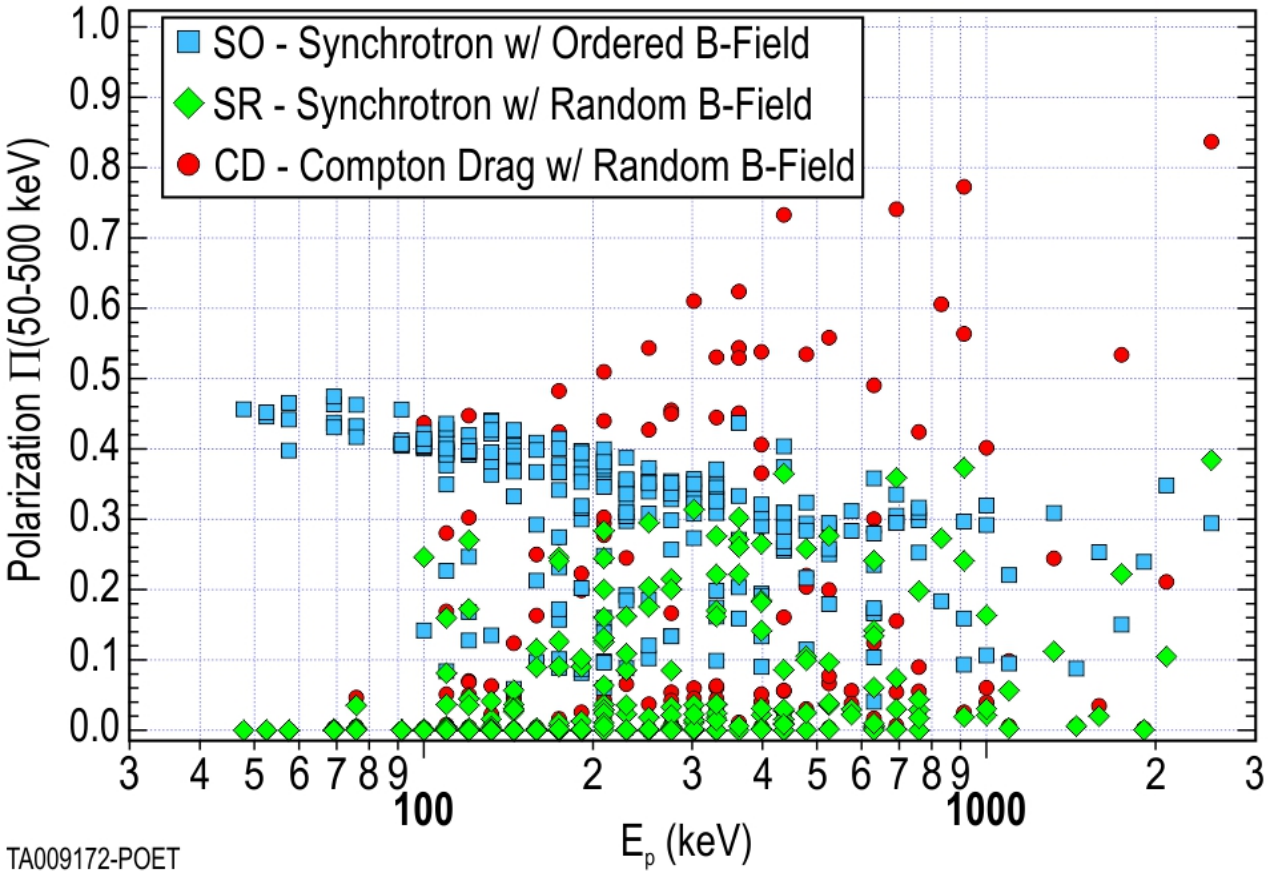
Yamagata University · The University of Alabama in Huntsville · NASA · University of New Hampshire · SwRI Southwest Research Institute

Polarization Distributions



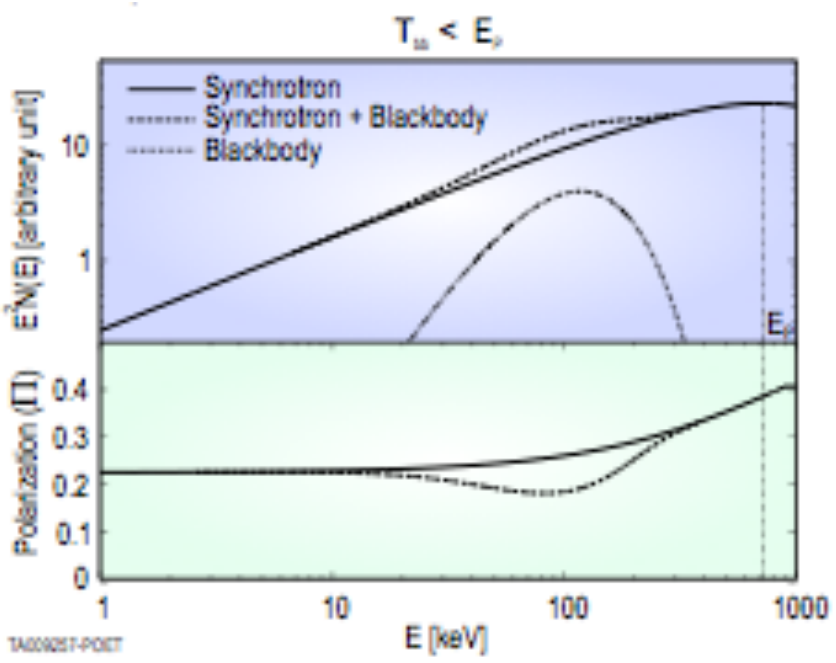
Polarization Distributions

Toma et al., ApJ, 698, 1042 (2009)

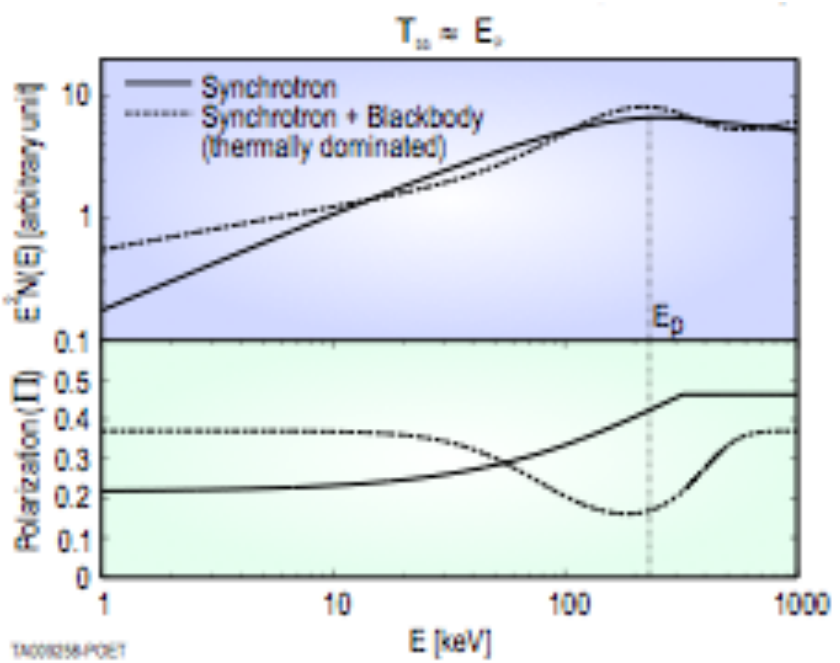


Energy-Dependence of GRB Polarization

Different emission mechanisms predict a different dependence of polarization on energy. If the typical Band spectrum is synchrotron- dominated, E_P would correspond to a break in the non-thermal electron spectral distribution, with a characteristic change in ∏ near E_P.

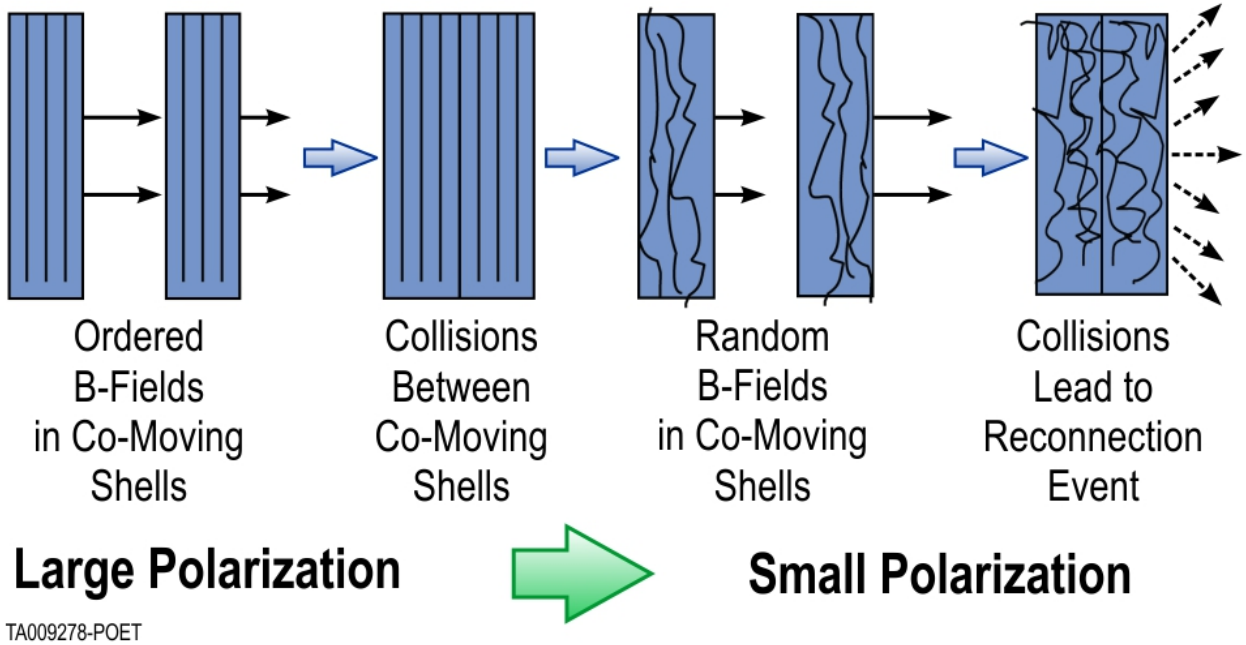


A simple blackbody component, seen in some GRBs, results in a reduction of P near the location of the blackbody peak.



A modified blackbody spectrum approximates the Band spectrum, but exhibits very different polarization properties.

Time-Dependence of GRB Polarization



The ICMART model (Zhang and Yan, 2011) predicts that interacting shells within the outflowing jet will lead to increasingly random magnetic field structures that eventually produce reconnection events.

The Importance of LEAP

- Polarimetry is the next step towards our understanding of the GRB physics. Until now, studies have concentrated on time histories and spectra. Now is the time to move forward with polarimetry.

- Probing the central engine of GRBs provides insight into the nature of astrophysical jets, which are ubiquitous in the Universe.

- LEAP will provide correlated measurements of GRBs with gravitational wave observatories at a time when Swift and/or Fermi may no longer be available.